INTERTROPICAL CONVERGENCE ZONE AND MEAN CLOUD AMOUNT IN THE TROPICAL PACIFIC OCEAN

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ABSTRACT

The mean positions of the intertropical convergence zone in the Pacific Ocean, determined by analysis of the surface wind constancy and resultant vector winds, is compared with mean total cloud cover based upon TIROS data averaged over 2° squares of latitude and longitude in the equatorial Pacific.

1. INTRODUCTION

The purpose of this paper is to investigate the association of mean cloud cover patterns with the mean surface position of the intertropical convergence zone (over an ocean area) that has been determined through wind observation statistics.

Mean climatological positions of the intertropical convergence zone in the Pacific have been determined by mean streamline patterns and air mass analysis (Brooks and Braby [9], Alpert [6, 7, 8], Nagler [15], Riehl [17], and Watts [22]). Also, a mean doldrum belt position has been identified (Admiralty Hydrographic Department [1]) by the frequency of reported bad weather and by the minima of mean atmospheric pressure. The mean positions of the intertropical convergence zone and doldrum belt determined by the above authors are in close agreement.

Mean total cloud cover over the tropical Pacific Ocean has been published (U.S. Weather Bureau [20], Air Ministry, Meteorological Office [4], U.S. Navy [19], and U.S. Naval Oceanographic Office [18]). These works are all based upon island data, or data from shipboard observations summarized over large ocean areas. Since the launching of the first TIROS meteorological satellite, however, data have become available for a more detailed study of cloud systems. An analysis of mean cloud cover over the globe based on TIROS data was presented over 5° squares of latitude and longitude by seasons (Clapp [10]). The scale of this analysis was much too large to study characteristics of a convergence zone, but 2° square averages for monthly periods should show adequately the tropical cloud cover patterns of the convergent area for purposes of this paper.

2. WIND AND THE INTERTROPICAL CONVERGENCE ZONE

The classical model of the intertropical convergence zone consists of the convergence of the Northern and Southern Hemispheric trade wind systems near the Equator. The characteristic steadiness of the trade winds is expressed by high values of wind constancy, which is defined by the following:

$$\text{Constancy} = 100V_r/\overline{V}$$

where V_r=mean vector wind speed and $\overline{V}$=mean wind speed. Thus, a wind system with large variations in speed and direction would have low constancy. In the convergence zone the trade winds slow down and change direction. Therefore, in the intertropical convergence zone itself, one would expect to find a minimum of wind constancy. Riehl [17] has published meridional profiles of the equatorial region which show the mean distribution of pressure and wind constancy in relation to the axis of the equatorial trough or convergence zone. This work shows that the equatorial trough is indeed a region of minimum wind constancy.

Mintz and Dean [14] have shown, through charts of wind constancy in the Pacific, that minimum constancy is also associated with the subtropical anticyclones. Their charts for January and July show a zone of minimum constancy emanating from the subtropics of the South Pacific in the region from 160°W. to 180° longitude and extending westward and northwestward into the doldrums. From the map series of the U.S. Weather Bureau's Spaceflight Meteorology Group [21], it is evident that these zones of minimum wind constancy are associated with the mean northward movement of frontal systems traveling from the southern mid-latitudes. These mean frontal positions have also been indicated on climatological charts prepared by the Royal New Zealand Air Force (Gabites [12]).

In addition, minima of wind constancy may arise where the large-scale wind flow is altered by summer low pressure areas over land masses. Within the Pacific region, minima of wind constancy produced by this phenomenon may be found near the northwest coast of Australia and near the southwest coast of Mexico.

It is evident that minimum constancy cannot be used exclusively to indicate the climatic positions of the intertropical convergence zone. In this paper, the mean position of the intertropical convergence zone was determined to be the zone where wind constancy was of low value, relative to the values north and south of the zone, and where vector mean winds indicated convergence of streamlines. Surface wind constancy was computed from a surface wind data summary completed by the U.S. Naval Oceanographic Office [18]. These data were averages for 5° squares of latitude and longitude for the record period 1854 through 1959.

The actual width of the convergence zone is not well established; it seems to be on the order of a few degrees of latitude in the eastern Pacific (Admiralty Hydrographic Department [1]). It would seem incongruous to use 5° square averaged wind data for analysis of this smaller scale convergence system. Although constancy values and vector mean winds were computed from 5° square averaged data, the position of the convergence zone was inferred to be in the area between opposing wind vectors with minimum constancy.

3. MEAN TOTAL CLOUD COVER IN THE TROPICAL PACIFIC

Unlike the wind data, no vector quantities were involved in the analysis of cloud data. Positions of cloud cover maxima could not be inferred from cloud information outside of the maximum cloudiness areas. For this reason the mean total cloud cover for each 2° square of latitude and longitude in the tropical Pacific Ocean was computed. This was done by utilizing TIROS nephanalyses for the months of January 1963, 1964, 1965, and August 1961, 1962, 1963, and 1964. Until 1965 seven categories of cloudiness were delineated on the nephanalyses; after this time only four were used. The categories of cloudiness and the corresponding approximate equivalences of cloud cover are presented in table 1. The method used for determining the mean cloud cover in each 2° square was to count the nephanalysis cloudiness categories occurring in each area during the averaging period.

TABLE 1.—*Categories of cloudiness and approximate equivalences of cloud cover in TIROS nephanalyses*

Sky condition	Clear	Clear var. scat.	Scat.	Scat. var. broken	Broken	Broken var. overcast	Overcast
Tenths of cloud cover	0–1	2–3	4	5–6	7	8–9	10
Old nephanalysis code	1	2	3	4	5	6	7
New nephanalysis code	1		2	3		4	

TABLE 2.—*Weighting factors for categories of cloudiness in TIROS nephanalyses*

Old nephanalysis code	1	2	3	4	5	6	7
Weighting factors	2	2	1	2	1	2	1
New nephanalysis code	1		2	3		4	
Weighting factors	4		1	3		3	

The category frequencies were then weighted according to a scheme illustrated in table 2. It was necessary to weight the category frequencies because the conventional scale of cloud cover in tenths was unevenly apportioned among the nephanalysis cloud cover codes. The weighted frequencies were multiplied by the mean cloud amount of the respective nephanalysis categories and summed. This total was divided by the sum of weighted frequencies to get the mean cloud cover for the 2° square. The frequency distribution of cloud cover amounts over tropical maritime areas has not been clearly established. A uniform frequency distribution has been assumed in the assignment of weighting factors.

4. WEATHER ACTIVITY AND THE INTERTROPICAL CONVERGENCE ZONE

It has been demonstrated that the climatological region of maximum weather activity in the equatorial region may not necessarily be centered on the surface position of the intertropical convergence zone based upon streamline and air mass analysis (Air France [2,3]). Alaka [5], Koteswaram [13], Reiter [16], and Flohn [11] have shown that the weather activity in the equatorial region is closely associated with the position and strength of strong easterly winds aloft. Displacement in position between the tropical convergence zone at the surface and the areas of maximum cloudiness over the Pacific Ocean is crudely indicated when Riehl's [16] streamline convergence patterns are compared with the cloud climatology of the tropical Pacific published by the U.S. Naval Oceanographic Office [18].

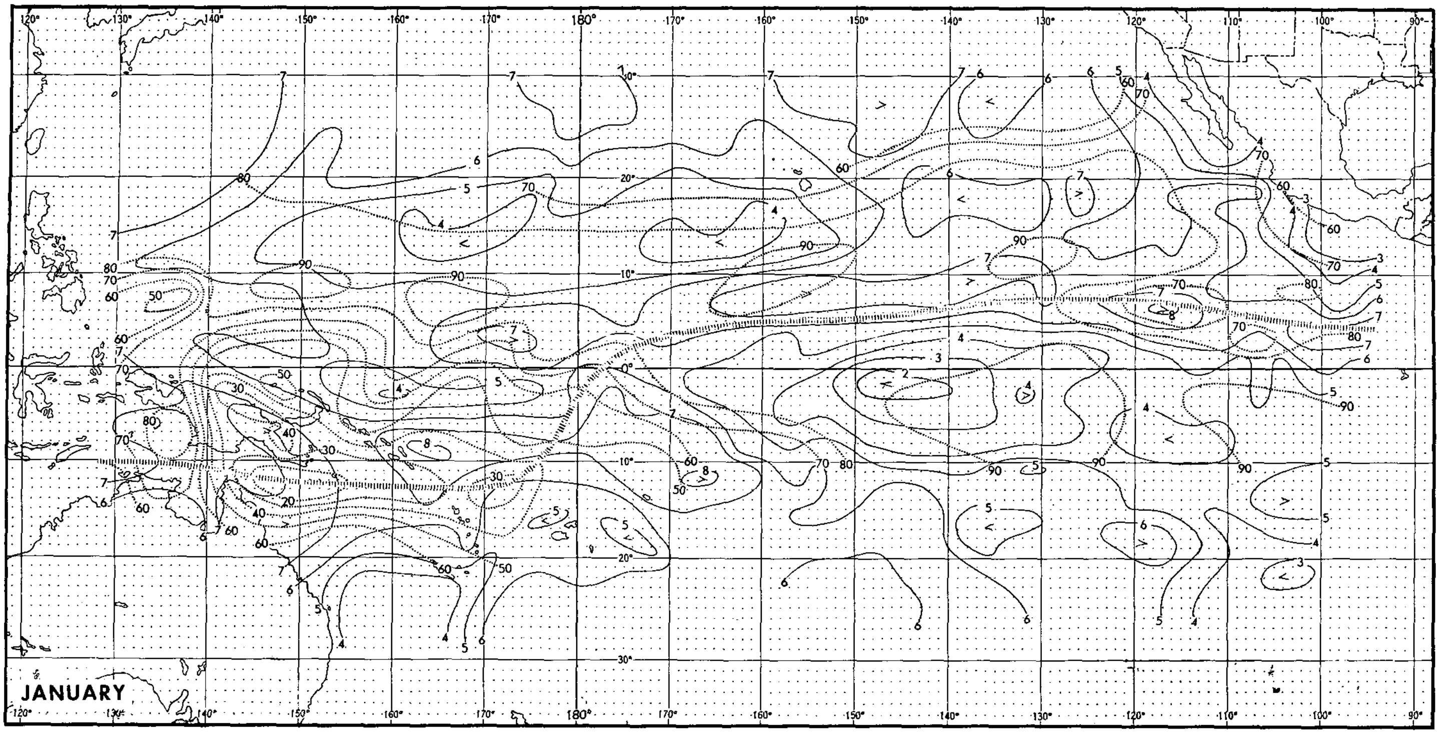

FIGURE 1.—The January means of the surface position of the intertropical convergence zone (broad hatched line), surface wind constancy (dashed isopleths, labeled in percentages), and total cloud amount (solid isopleths, labeled in tenths of sky cover).

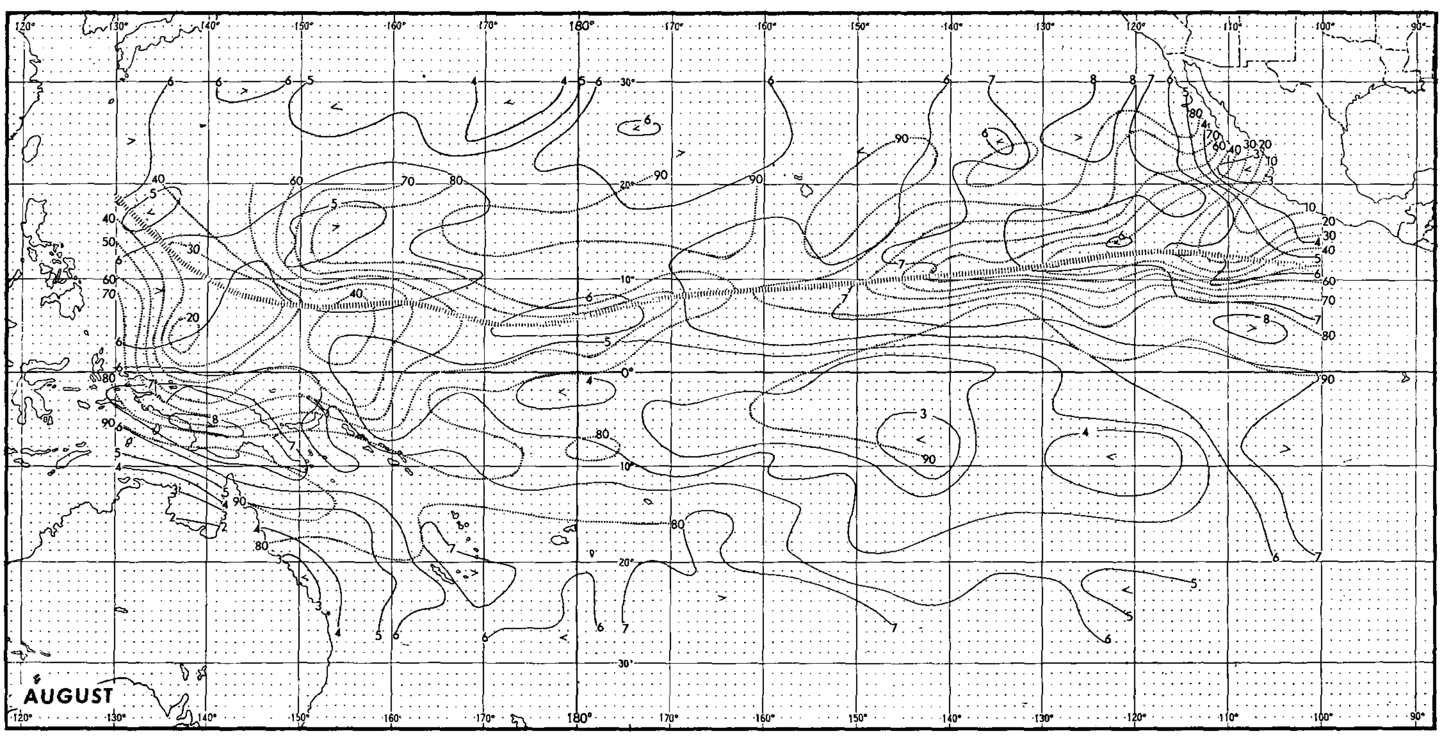

FIGURE 2.—The August means of the surface position of the intertropical convergence zone (broad hatched line), surface wind constancy (dashed isopleths labeled in percentages), and total cloud amount (solid isopleths, labeled in tenths of sky cover).

5. INTERTROPICAL CONVERGENCE ZONE AND MEAN CLOUD AMOUNT

Figures 1 and 2 present the mean surface position of the intertropical convergence zone, the mean surface wind constancy, and the mean total cloud amount for January and August, respectively. In all regions of the tropical Pacific the intertropical wind convergence zone does not pass through the lowest values of surface wind constancy because some areas of minimum constancy are not directly associated with convergence between Northern and Southern Hemisphere wind systems. There was less objectivity in locating the convergence zone near the Mexican coast because low wind constancy, produced by continental circulation effects, is inseparable from minimum constancy produced in the zone of hemispheric wind convergence. In this region more reliance was placed on the vector mean wind and continuity of position for location of convergence zone position than on the constancy values. The continuity of the zone position was established by the author's unpublished monthly series of vector mean wind charts.

If one were to view the whole region within 300 mi. or so on either side of the mean position of the convergence zone as a region where broad-scale vertical motion exists all the time, the region is a zone of potential weather development. High frequency of weather activity may then be expected to occur within this region not necessarily centered on the zone itself. This activity is normally restricted to a narrow band within the zone.

Positions of frequent weather activity may be indicated by maxima of cloud cover. These in turn may be associated with the mean position of mechanisms in the convergence region that trigger frequent weather development.

The climatological cloud cover maxima are presented together with the mean center position of the tropical convergence zone in figures 1 and 2 to illustrate the displacements between the positions of cloud cover maxima and convergence zone centers.

Some displacements of maximum cloud cover and the center of the convergence zone are quite large. For example, in the area from 130°W. to 100°W. longitude the maximum cloud cover zone dips southward and is south of the surface wind convergence zone in August but agrees in position with the convergence zone in January. In figure 1, the January position of the intertropical convergence zone is in the Southern Hemisphere west of longitude 180°. This is evident from the mean streamline patterns. However, in January, as well as in August, a minimum of constancy exists near the Equator as well as along the convergence zone, and the mean cloud cover along the northern edge of the Equator is as great as that in the zone itself.

Some displacements are small. For example, in the central part of the Pacific, east of 180° and west of 130°W., the maximum zone of cloud cover is about 3° north of the surface wind convergence zone position. It is possible that this displacement was caused by differences in the areas over which the wind and cloud data were averaged. However, the mean vector winds of the 5° square from 5° to 10°N. latitude all have southerly components, while those in the area from the Equator to 5°N. latitude have little or no meridional components. Therefore, it is unlikely that the wind convergence zone should be positioned farther north. The intensity and position of the cloud cover in this zone in August (fig. 2) is little changed from that of January; however, the convergence zone moves northward somewhat in August, and at this time the convergence zone and maximum cloudiness zone are positioned together. This indicates some degree of independence between the amount of weather activity and the position of the center of the convergence zone itself.

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